Ballville Dam Project
Draft Environmental Impact Statement:

Appendix A Addendum

6- Sediment Transport Memorandum

Memo

Stantec

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INTRODUCTION

The purpose of this memo is to provide a qualitative description of the expected channel response and the subsequent biological response associated with the proposed removal of Ballville Dam on the Sandusky River near Fremont, Ohio. This memo addresses potential impacts associated with sediment release during and after removal of the dam on the following four items:

1. Navigation;
2. Flood conveyance and capacity;
3. Water quality; and
4. Aquatic biota.

BACKGROUND

The U.S. Fish and Wildlife Service (USFWS) is the lead agency for developing a Draft Environmental Impact Statement (DEIS) for the Ballville Dam Project. The USFWS is the lead agency based on the funding commitment of $2 million from the Great Lakes Restoration Initiative (GLRI) through the Great Lakes Fish and Wildlife Restoration Act (Act)(16 U.S.C. 941 §4321 et seq.). The Act authorizes the USFWS to work in partnership with States, Tribes, and other Federal agencies for the restoration of fish and wildlife resources in the Great Lakes Basin.

Issuance of funding under the Act constitutes a discretionary federal action by the USFWS and is thus subject to the National Environmental Policy Act (NEPA). As the lead agency, the USFWS has determined that an Environmental Impact Statement is appropriate for meeting compliance with the NEPA. The NEPA process requires that federal agencies integrate an interdisciplinary environmental review process that evaluates a range of alternatives, including the No Action Alternative, as part of the decision-making process. This memorandum was developed ahead of the NEPA document to assist in preparation of the environmental consequences chapter of the DEIS for the project.

CONCEPTUAL DAM REMOVAL APPROACH

Four alternatives, including the No Action Alternative, are being evaluated in the DEIS. The Proposed Action is divided into three phases with each phase having multiple objectives for meeting dam removal goals. In summary, the phases are:

- Phase 1
  - Construct access to south abutment (September 2014)
  - Notch spillway to elevation 615 feet (November 2014)
- Phase 2
  - Sediment stabilization (March 2015)
  - Construct ramp (May-June 2015)
  - Construct Ice Control Structures (July-October 2015)
  - Remove dam (September-November 2015)
  - Channel restoration (November-December 2015)
- Phase 3
  - Bank stabilization/planting/in-stream work (Summer 2016)
  - Remove any remaining pieces of dam designated for removal and modify sea wall (August-November 2016)
  - Remove Tucker Dam (if necessary; Fall 2016).

CHANNEL RESPONSE OVERVIEW

The entire Proposed Action is segmented into three phases; each with sub-phases designed to complete the project in the least environmentally damaging way. Phase 1 would remove a small section of the dam resulting in a “notch” in the south spillway of Ballville Dam that is 20 feet wide and 10 feet tall. Notching the dam would produce a base level change and would lower the hydraulic control on pool elevation from 625 to 615 feet at low flows. The upstream channel within the former pool would be expected to respond to this new elevation control with a series of adjustments such as upstream knickpoint[1] migration, incision, and subsequent below water channel widening (Schumm and Parker 1973, Womack and Schumm 1977). This cycle of knickpoint migration, incision, and widening would likely occur repeatedly until a new stable bed elevation is achieved along the length of the impoundment. However, it is possible that the next phase of dam demolition would begin before the process of adjustment is complete. Fine-grained sediments would be mobilized and exported to downstream reaches during and immediately after construction associated with the notch. The magnitude of sediment export would be limited by the relatively small hydraulic capacity of the notch (Riggsbee et al. 2007) and may not differ substantially from the existing condition. Coarse-grained sediments, if present, are not expected to pass over the dam. Additional sediment would be exported by storm-generated stream flows in the months following the notch.

The remainder of Ballville Dam would be demolished during Phase 2. Channel adjustment and sediment export would follow similar processes described above. However, channel incision

[1] A “knickpoint” is a localized area of high channel slope and is often a focal point for channel adjustments.

would be constrained by currently submerged bedrock outcrops rather than the dam. A pulse of stored sediment would be exported to downstream reaches during the demolition process. Subsequent pulses would be mobilized during storm generated high flow events. The impoundment would no longer constrain the physical forces necessary to mobilize and transport coarse-grained substrates.

It is not possible to calculate the exact volume of sediment discharge using currently available scientific methods. However, studies from other dam removal projects can be used to place sediment loads in context (Major et al. 2012). The Marmot Dam, on the Sandy River in Oregon, was demolished in a single rapid breach. Fifteen percent of the total stored sediment volume was exported downstream in the first 60 hours after breaching. Another 35 percent was exported during the winter wet season following the initial breaching of the dam. Storms in the winter months of the second wet season resulted in an additional six percent of the total sediment yield from the former impoundment, which suggests that the channel approached a dynamic equilibrium. Thus 44 percent of the total stored sediment volume remained in place and was not transported to downstream reaches of the Sandy River.

The notch strategy is intended to diminish the initial delivery of sediment to downstream reaches by limiting the depth of incision to elevation 615 feet rather than the much lower bedrock elevation of 596 feet. This strategy also constrains storm driven export because the impoundment would maintain backwater conditions during higher flows. The dimensions of the notch are only large enough to convey approximately 2,000 cubic feet/second (cfs), which is large enough for approximately 90 percent of the summer and autumn discharge values. Larger flows would continue to produce backwater conditions behind the dam. Under the backwater conditions both slope and velocity would be reduced thereby limiting shear stress available to initiate sediment mobilization. Riggsbee et al. (2007) demonstrated that backwater conditions caused by a notch limited both sediment concentrations and overall loading during storm events in comparison to measurements collected after complete removal of the dam. The notch would concentrate flows on one side of the dam and would allow demolition to occur under drier conditions. The notch would also draw down the pool level enough for seeding to occur on approximately 20 acres of formerly submerged areas in an attempt to limit erosion and mobilization of fine grained sediment.

NAVIGATION

Demolition of Ballville Dam and the subsequent release of sediments would result in localized accumulation (aggradation) of sediment in the reach downstream from the dam. Prior studies of dam removal (Doyle et al. 2005, Major et al. 2012) have documented the formation of a “sediment wedge.” Currently available scientific methods do not allow for accurate predictions regarding the initial location of the sediment wedge or its size. Sediment transport modeling conducted by Stantec (2011) suggests that depths of sediment aggradation would vary spatially. The results of the 1-dimensional sediment transport analysis indicate that the maximum height of aggraded sediment would be approximately 2.5 ft in the reach of the river confined by levees through Fremont; however, typical depths of sediment would be less than 1 ft. Note that this analysis did not include evaluation of localized aggradation, which could result in greater reductions in depth. The maximum sediment aggradation depths were calculated during summer low flows; the stream power generated by the river through the leveed section even during small flood events (i.e. the 5- or 10-year flow) is sufficient to transport enough volume of sediment to bring the channel back to pre-dam breach conditions.

Regardless of the sediment wedge's initial size and position, it would be expected to degrade over time as it migrates downstream and as sediment is redistributed over a larger area with each successive high flow event. The rate of wedge migration and sediment dispersal are dependent upon the flow regime over a period of years following removal of the dam. If the dam removal is followed by a succession of large flow events, the rate of wedge migration and sediment redistribution would be more rapid. If flows are small, channel would likely respond less quickly. The sediment wedge that formed following removal of Marmot Dam was still present after two years and contained approximately 25 percent of the total volume of sediment eroded from the reservoir (Major et al. 2012).

The Marmot Dam example differs from the Proposed Action in several significant ways. First, a substantial fraction of the sediment stored behind Marmot Dam was comprised of gravel and larger sized sediments. These coarse grained sediments were deposited in the sediment wedge whereas sand and smaller-sized particles were transported beyond the wedge and broadly dispersed further downstream (Major et al. 2012). Gradation analysis on bulk samples of seven vibracores collected from the Ballville Dam impoundment showed that over 90 percent of the material stored behind the dam was comprised of silt and clay (AECOM 2010). These particles have very low entrainment thresholds and would mobilize more readily than the sediments that formed the wedge associated with the Marmot Dam removal. Second, Marmot Dam was breached in a single event and 89 percent of the total sediment transport occurred in the first winter after demolition (Major et al. 2012). Ballville Dam would be demolished in phases over a 14 month period. This approach was designed to result in the release of smaller volumes of sediment over a longer time frame (not one event). This is expected to minimize the size of the sediment wedge and the magnitude of suspended sediment associated with any given storm event (see Riggsbee et al. 2007).

The sediment wedge would not be expected to form immediately below the dam due to the small grain size of the sediment stored in the pool as well as the relatively steep gradient of the river reach between the dam and the U.S. Army Corps of Engineers (USACE) flood control project. Some sediment may deposit in the levee section during low flows, however, the absence of a floodplain (due to the levee confinement) greatly increases near bed shear stresses and stream power during high flows. Consequently, high flow sediment transport capacity would be expected to be very high in this part of the Sandusky River. The reach of the river near Brady's Island is potentially susceptible to sediment aggradation, particularly the side channel on the eastern end of the island. Therefore some short-term impacts to motorized watercraft navigation may occur there and elsewhere in the lower river. However, the effect of the sediment wedge diminishes with distance from the dam due to: (1) the dispersal of sediment over a larger area; (2) deposition of sediments on bars, islands, and floodplains; and (3) the export of the smallest particles to Lake Erie.

Impacts to navigation in the Sandusky River, Muddy Bay, and Sandusky Bay may be placed in perspective by comparing the sediment volume stored by Ballville Dam to the total surface area available for deposition. If it is assumed that 470,400 cubic yards (CY) would be exported following dam removal (consistent with Major et al. 2012) and that sediment would deposit on less than ¼ of the surface area available, then the depth of deposition would be approximately 3/8 of an inch. Even if the entire volume stored by the reservoir was mobilized, the depth of deposition would be only 2/3 of inch. Consequently, it is unlikely that Ballville Dam removal would cause long term impacts to navigation. It is also important to recognize that loading from removal of the dam would be small in comparison to loading from the Sandusky River watershed. It is currently estimated that 840,000 CY are stored in the impoundment. Between 1979 and 2002, the Sandusky River watershed delivered 8,828,000 CY yards of sediment to the USGS Gauge 0419800 located at Tindall Bridge. Approximately 867,000 CY were delivered by the watershed in a single year and 143,000 CY in a single day (Stantec 2011). The mean annual load is approximately 368,000 CY, nearly half the estimated volume of material currently stored in the impoundment (840,000 CY). While dam removal would certainly contribute sediment to the river, in most years loads would fall within the natural range of variation for the watershed.

FLOOD CONVEYANCE AND CAPACITY

The potential for sediments currently stored upstream of Ballville Dam to affect flood conveyance and capacity in the Sandusky River near Fremont was covered in greater detail by the Ballville Dam Removal Feasibility Study (Stantec 2011). The potential for increased flooding in Fremont was not identified as a critical issue because of (1) flood capacity associated with the freeboard of the levee system, and (2) the high sediment transport capacity of river during high flow events.

Sediment transport modeling was performed using hydrologic and sediment data from the USGS gage located upstream of the Ballville Dam at Tindall Bridge. The modeled scenarios included “wet” and “dry” years as well as “heavy” and “light” sediment loading. Results indicate that aggradation of sediment is likely to occur in downstream reaches, but that this aggradation would not result in increases of water surface elevations in excess of 1 ft through the leveed reach in Fremont. This is below the available freeboard within the levee system. To state in another way, if the “dry” condition occurs and the maximum aggradation is observed, the sediment would be flushed out of the leveed section on the rising limb of the flood hydrograph before the peak flow occurs. The most pronounced area of sediment aggradation appeared near the Highway 20 Bridge north of Fremont and resulted in a water surface elevation increase of less than 0.1 ft. Localized shoaling of sediment could occur depending on various factors including, but not limited to, the flow regime, river morphology, and flow obstructions.

WATER QUALITY

The magnitude and duration of water quality impacts resulting from dam removal depend on many factors including:

- the volume and composition of sediments stored upstream of the dam;
- river discharge at the time of the breach and in the months that follow;
- suspended solids and/or turbidity concentrations at the time of the breach;
- channel slope;
- basin area;
- time that has passed since demolition; and
- the distance from the dam location.

There have been other dam removals on the Sandusky River in Ohio. The St. John's Dam was a 151 feet long by 7.2 feet high dam located upstream of the Ballville Dam on the upper Sandusky River. This dam was breached in a two phase process. Phase 1 involved breaching the dam with a 13.1 by 3.3 feet notch (Granata et al. 2008). Phase 2 completely removed the dam. The dam stored approximately 250,000 CY of sediment comprised of sand and gravel. Notching of the dam occurred on March 18, 2003, on the falling limb of the hydrograph at a flow of 2,659 cfs. The increase in suspended solids resulting from construction activity was negligible in comparison to suspended solids loading from the watershed. Suspended solids concentrations prior to the notch were approximately 140 parts/million (ppm) and continued to decline for the duration of construction activities.

Complete demolition of St. Johns Dam occurred on November 17, 2003. Discharge during the demolition was approximately 71 cfs. Demolition of the dam produced a temporary flood wave that peaked at 1,166 cfs and attenuated within eight hours. Suspended sediment concentrations prior to demolition were approximately 20 ppm and increased sharply to 59 ppm but returned to pre-demolition levels in less than 24 hours. By June of the following year (2004), turbidity levels measured below the dam location were indistinguishable from turbidity levels measured upstream of the former dam. This was true for both moderate flow conditions (177 cfs) and storm events (1,413 cfs) that produced concentrations of approximately 60 Nephelometric Turbidity Units (NTU) and 130 NTU respectively. These results suggest that after only seven months, the delivery of sediment from the upper watershed overshadowed sediment delivered from the reservoir.

Marmot Dam on the Sandy River in Oregon was breached in a single event in October of 2007 (Major et al. 2012). Peak suspended sediment concentration during the breach was 49,055 ppm and turbidity approached 1,000 NTU. Suspended sediment concentrations in the months that followed were a function of discharge and dropped off quickly after storm events. Concentrations during storms following the breach often exceeded 10,000 ppm but concentrations during baseflow were generally less than 10 ppm. Turbidity measurements exhibited a similar pattern with storm events generating the highest concentrations (100 – 1,000 NTU) followed by extended periods of low concentrations during lower flows (0.1 – 10 NTU). By

December of 2007, less than three months after the demolition, suspended solids concentrations returned to levels that were similar to an upstream control station. The spatial extent of water quality impacts dissipated within six miles of the dam location, even in the months immediately following demolition.

Sethi et al. (2004) measured total suspended sediment concentrations upstream and downstream of a demolished dam on Koshkonong Creek in Wisconsin. They did not report stream discharge values for the dates when water quality samples were collected but based on the range of values it appears that most samples were collected during low flow periods because of the low concentrations observed (0.005 to 1.0 ppm). Concentrations differed significantly between the upstream and downstream sample locations, with downstream locations having the highest concentrations. Elevated concentrations were observed over 2.5 years after dam demolition. However, although concentrations differed in a statistical sense, it is unlikely that the observed differences were biologically meaningful because the overall low concentrations (e.g., 0.005 to 0.05 ppm) fell well below effect thresholds for most organisms (Newcombe and Jensen 1996).

The Lowell Mill Dam on the Little River in North Carolina was demolished over a period of approximately eight months. Demolition occurred in three phases. First was removal of the flashboards controlling the pool elevation; eight months later the dam was breached to grade; and within two weeks of the initial breach, the dam was completely demolished (Riggsbee et al. 2007). The maximum observed suspended sediment concentration (approximately 70 ppm) occurred as a result of the first big storm event following complete removal of the dam. The maximum concentration observed at an upstream sample point was approximately 30 ppm for the same sample period. Although concentrations at the upstream and downstream sample locations differed during storm generated high flow periods they rapidly approached unity on the receding limb of the hydrograph after only two to three days. Riggsbee et al. (2007) also concluded that elevated total suspended solids loads dissipated less than 6.2 miles from the dam location and were indistinguishable from upstream loads.

In all of the examples above, suspended sediment concentrations were naturally high during storm events and dam removal caused additional incremental increases in concentrations. Concentrations remained high for the duration of the storm event and in the days after as the hydrograph receded to base flow levels. High concentrations dissipated with increased distance from the dam and were similar to upstream values within approximately six miles of the demolition site. Concentrations during base flows were low and equaled or approached concentrations observed prior to demolition. With the exception of Marmot Dam, observed concentrations generally fell below effect thresholds for aquatic biota (see following sections). The Proposed Action, like the Lowell Mill Dam and the St. Johns Dam, would employ the use of a notch to control concentrations in the early stages of dam removal. The Proposed Action would also re-seed approximately 20 acres of exposed sediment upstream of the dam with the intent to stabilize as much sediment in place as possible. Demolition for the Proposed Action would be sequenced to occur in the fall, just before the onset of the wet season. The timing of construction is important because it would avoid making releases during the low flow summer months when water quality impacts would be the greatest and when the river has the least capacity to move sediment. Ballville Dam is fairly large and the Phase 2 demolition would require several days, perhaps weeks. This approach differs significantly from the Marmot Dam where the breach occurred almost instantaneously. The slower approach for lowering the base levels should help to keep suspended sediment concentrations low in comparison to Marmot Dam.

AQUATIC BIOTA

FRESHWATER MUSSELS

Stantec (2012a) surveyed the Sandusky River between the Ballville Dam (RM 18.0) and the Hayes Avenue Bridge (RM 16.0) in September 2011. Seventy-nine live animals, comprising 13 species were observed. No Federally listed taxa were found, however, one live three-horned wartyback (*Obliquaria reflexa*), an Ohio threatened species, was observed as were 23 deertoe (*Truncilla truncata*), an Ohio Species of Concern. Freshwater mussels may be adversely impacted by one of four mechanisms: (1) direct impacts from construction and/or the operation of heavy equipment; (2) stranding caused by stage changes resulting from demolition of the dam; (3) scour and mobilization of bed substrates resulting from increased stream power after demolition of the dam; and (4) increased sediment load to downstream reaches. Impacts from construction would be avoided by limiting construction to areas near the dam. The exposed bedrock in the area immediately below the dam provides very poor habitat and no live mussels were found during 2011 surveys. Impacts from the pool drawdown and headward channel incision would be minimized by capturing and relocating stranded freshwater mussels to locations outside of the drawdown area. Relocation of mussels would be consistent with agency approved study plans.

The Proposed Action would cause short-term, temporary increases in sediment load downstream of the current dam location. Potential effects to freshwater mussels include physiological stress from elevated suspended sediment concentrations and habitat changes resulting from increased sediment load. Increased sediment load in rivers is a frequently cited cause for widespread mussel population declines (e.g., Brim Box and Mossa 1999). However, some studies indicate that freshwater mussels can endure short term environmental stressors by closing their valves and entering a quiescent state (Sheldon and Walker 1989, Haag 2012). In a review of sediment focused literature, Haag (2012) concluded that increased sedimentation was a plausible explanation for some localized extirpations but that there was “an almost complete lack of direct evidence” linking sedimentation to enigmatic freshwater mussel declines.

Suspended sediment concentrations

The influence of suspended sediment concentrations on freshwater mussel distribution and abundance has been infrequently researched. Bucci et al. (2008) conducted laboratory experiments on freshwater mussel feeding at various suspended sediment concentrations.

They found that valve gape (an indication of feeding activity) for fat muckets (*Lampsilis siliquoidea*) during periods of low (<20 NTU) and high turbidity (20 – 75 NTU) did not differ significantly, whereas valve gape for the invasive Asiatic clam (*Corbicula fluminea*) did. The experimental concentrations did not reach levels sufficient to cause valve closure in the fat mucket. However, the test concentrations were higher than those observed during base flow for the three case studies where NTU values were reported (Granata et al. 2008, Sethi et al. 2004, Majors et al. 2012) suggesting that normal feeding for this species would not be impaired by the Proposed Action.

Beussink (2007) exposed fish, infested by larval mussels (glochidia), to high concentrations of suspended sediment ranging between 1,000 and 5,000 ppm for a 48 hour period. Increased sediment concentrations resulted in reduced gill attachment and metamorphosis rates. Sediment treatments equal to 5,000 ppm often, but not always, resulted in greater than 90 percent mortality for the glochidia. However, glochidial metamorphosis rates for lesser sediment concentrations ranging between 1,000 and 2,500 ppm were often statistically indistinguishable from experimental controls (0 ppm). The exact threshold for the lethal effect was not determined in this study but is likely higher than the maximum observed concentration in the Sandusky River (2,420 ppm) for the period between 1979 and 2002.

Burial

One plausible mechanism for adversely affecting freshwater mussels is burial by increased sediment load. Marking (1979) (as cited in Watters 1999) found that 50 percent of fat muckets and pocketbooks (*Lampsilis cardium*) could successfully extricate themselves when buried in sediment to a depth of nearly seven inches. A similar proportion of Wabash pigtoes (*Fusconaia flava*) self-extricated from a depth of only four inches, an indication of the differential abilities among species. Krueger et al. (2007) experimentally buried mussels under nearly 16 inches of sediment and observed between six and 13 percent mortality after 48 hours. The exact cause of mortality was not determined but was probably sediment anoxia. Sheldon and Walker (1989) studied two freshwater mussel species in a laboratory setting and found differential susceptibility to low oxygen concentrations between species that primarily occur in lentic (lake like) habitats and those that occur in lotic (flowing water) habitats. Species that rely on riffles, runs, and other habitats with fast flowing oxygenated water were less able to tolerate low oxygen concentrations.

Lewis and Reibel (1984) studied the burrowing behavior of three mussel species in liquefied mud, compacted clay, sand, and washed gravel. Animals placed on their side in liquefied mud had difficulty turning to an upright digging position but were able to burrow as a result of depressions caused by the weight of the animal and frequent expulsion of water from the siphons. Rates of burrowing in the remaining substrates varied by species and grain size with the burial depths the lowest in the coarsest substrates. Nonetheless, the mussels were able to bury in widely divergent substrate types, indicating a high degree of adaptability to the varied conditions that mussels inevitably encounter in natural settings. These results confirm the work of Strayer (1981) and Hardison and Layzer (2001) among others documenting the flexible use of substrates by mussels.

Some burial and subsequent mortality of freshwater mussels in the low gradient reaches of the Sandusky River below the dam is probable, especially in areas susceptible to sediment aggradation. However, field and laboratory studies demonstrate that mussels can endure substantial deposition and in some cases levels that are greater than anticipated for the Proposed Action. It is also clear that mussels occur in a wide range of substrate size classes. Release of sediments from Ballville Dam would likely cause temporary reduction in sediment grain sizes in the reach downstream of the dam. If the extent of deposition is modest, then resident animals should be able to adapt to the changing conditions.

Response to Dam Removal

Few studies have directly examined the impact of dam removal on downstream mussel populations. Sethi et al. (2004) studied the response of a rapid dam breach on habitat and mussels in Koshkonong Creek in Wisconsin. Unfortunately, the experimental design did not include a control site so the results are difficult to interpret. The authors found that the total area of substrates comprised of silt and sand increased significantly over pre-project levels. This effect did not occur immediately but was observed nearly three years after the dam removal. Total mussel density did not differ from pre-project levels three months after the dam breach but was significantly lower in the third summer after removal. However, because of issues with the experimental design it is difficult to discern whether this decline was related to the dam removal, to natural population variability, or to factors related to search efficiency (e.g., river discharge, visibility, etc.).

More recently Heise et al. (2013) studied the effect of dam removal on mussel populations in the Deep River in North Carolina. This project differed from the one described in Sethi et al. (2004) in several ways. First, drainage area for the study site on the Deep River was an order of magnitude larger, the dam stored little sediment, and the drawdown occurred over weeks rather than hours. The authors observed short-term increases in fine-grained substrates in the year following the dam removal but sample locations returned to pre-project values in the second year of sampling. None of the mussel community metrics studied, including mussel density and species richness, detected significant effects from the dam removal.

Because of the emphasis on sediment control measures proposed for the Ballville Dam Project, it is anticipated that effects to downstream mussel populations, if any, would be short-term. Further, any adverse impacts would be offset by restored riverine habitat, elimination of a migratory barrier for fish (host) movement, and increased genetic exchange between isolated upstream and downstream populations. Further, both phases of demolition would be scheduled for the fall when stream temperatures are low and metabolic demand by mussels would also be low (Myers-Kinzie 1998) thereby minimizing the potential for physiological stress and mortality.

FISH

Potential adverse impacts of the Proposed Action for the Ballville Dam Project to fish include:

- physiological stress from increased suspended solids concentrations;
- feeding impairment;
- reduced reproductive success; and
- changes to structural habitat quality and composition from sediment deposition.

Physiological stress

Hesse and Newcomb (1982) studied the impact of flushing (sluicing) reservoir sediments on water quality and fish populations in the Niobrara River in Nebraska. In October 1976 reservoir flushing increased suspended sediment concentrations in the river. Turbidity was measured at 3,750 Jackson Turbidity Unit[2] (JTU), total suspended solids measured 21,875 ppm, and a fish kill was documented. Low dissolved oxygen concentrations were also implicated as a contributing factor in the fish kill. Subsequent monitoring between June and September of 1979 measured turbidity as high as 2,075 JTU and total suspended solids as high as 14,540 ppm without a fish kill. The maximum observed concentration in the Sandusky River between 1979 and 2002 was 2,420 ppm, far lower than concentrations described above. Further, the reservoir flushing on the Niobrara River produced concentrations six times higher than those observed on the Sandusky River without a fish kill. Hydraulic modeling suggests that concentrations for the Ballville Dam Proposed Action would be expected to range between 50 and 500 ppm (Stantec 2011), therefore lethal effects to fish from physiological stress are not expected.

The demolition schedule for the Proposed Action has been designed such that sediment releases would occur during the cooler months of the year when the metabolic demand of aquatic organisms is low and oxygen saturation in the water would be high. This would assist in minimizing any respiratory distress that might occur from elevated suspended solids concentrations. Also, many aquatic insects, amphibians, and other organisms would be entering periods of dormancy (e.g., pupation, aestivation, etc.) during the cooler months of the year.

Feeding Impairment

The potential for feeding impairment resulting from release of Ballville Dam sediments depends on the (1) physiological capabilities and the lifestage of the organism under consideration and (2) the ambient concentrations delivered by the proposed project. Some organisms prosper under elevated suspended sediment concentrations. For example, Walleye have a special layer in the retina that is extremely sensitive to light thereby enabling adult Walleye to forage for prey in dark and/or turbid environments that cannot be exploited by competitors (Kerr et al. 1997, Hartman 2009). However, there are limits to this ability. In a review of available literature, Kerr et al. (1997) concluded that Walleye foraging could be impaired at suspended sediment concentrations ranging between 200 and 300 ppm. Further, not all lifestages are equal and

[2] JTU and NTU are essentially the same measure of turbidity, however, differing in measurement methods.

younger fish are widely viewed as being more susceptible to stressors than adult fish. Walleye and Yellow Perch were reared as fingerlings for 28 days under a clear water and turbid treatment (>= 100 NTU) (Clayton and Morris 2009). Yellow Perch exhibited greater survival (79 +- 2.1%) under the turbid treatment than in clear water (54 +- 9.2%). Walleye survived better in clear water treatment (83 +- 2.0%) than in the turbid treatment (57 +- 6.0%). Mion et al. (1998) demonstrated reduced larval Walleye survival in the Maumee and Sandusky River associated with high river and sediment discharge.

Sensitivity to suspended solids also varies between species. For example, Walleye and Smallmouth Bass are classified as moderately tolerant to turbidity while other species that may be present in the project area, such as Silver Redhorse (*Moxostoma anisurum*) and Shorthead Redhorse (*Moxostoma macrolepidotum*) are intolerant of prolonged high turbidity (Trebitz et al. 2007). Unfortunately we were unable to obtain any studies characterizing suspended sediment thresholds for intolerant non-game species. Others, such as the Common Carp (*Cyprinus carpio*), Yellow Perch, Gizzard Shad (*Dorosoma cepedianum*; Gonzalez et al. 2010), apparently thrive on elevated suspended sediment concentrations and are often found in waters where average low flow turbidities exceed 100 NTU.

Prior studies of suspended sediment concentrations and dam removals indicate that concentrations may initially be high during the breaching of the dam but that concentrations quickly decline to approach background concentrations. Other periods of elevated concentrations occur associated with storm events and high flows. Thus impacts to water quality will consist of a series of punctuated periods of elevated concentrations that may occur over a period of one to three years (Sethi 2004, Riggsbee et al. 2007, and Major et al. 2012). Fish communities evolved to tolerate increased concentrations for short periods. Since anticipated concentrations from releases would be within the range of natural variability, any adverse effects of increased suspended sediments are expected to be temporary and short-term.

Reduced reproductive success

Reproductive success may be adversely affected by the Proposed Action through (1) burial of eggs from increased sediment loads, (2) increased suspended sediment concentrations that interfere with egg metabolism, and (3) increased suspended sediment concentrations that interfere with fish behavior. Comprehensive egg burial studies exist for salmonids and some estuarine species (see Newcombe and Jensen 1996) but are lacking for species known to occur in the project area. Jennings et al. (2010) examined incubating Robust Redhorse (*Moxostoma robustum*) eggs in substrates in laboratory tanks with varying degrees of fine sediment (between zero and 75 %) to determine if there was a threshold of deposition that was harmful to egg survival. Mean intragravel dissolved oxygen concentrations were higher in the zero and 25 percent treatments (7.5 to 7.6 ppm) than the 50 and 75 percent treatments (6.3 to 7.5 ppm). Survival to emergence was highest in the treatment without fine sediment (35 to 80 %), declined rapidly for the 25 percent treatment (0 to 20 %), and was essentially zero in the highest concentration treatments. While the Robust Redhorse does not occur in the project area, its behavior and habitat selection is similar to other extant redhorse species (e.g., Greater, River, Black).

Ambient water concentrations rather than substrate conditions are relevant to egg incubation and survival for species that deposit eggs on the surface of the stream bed or attach them to vegetation or other surfaces. Walleye eggs exposed to suspended sediment concentrations of 0, 100, 250, and 500 ppm showed no significant effects on survival (Suedel et al. 2012). In contrast, Gray et al. (2012) found that incubating Spotted Gar eggs had higher hatching success in clear water (94.8 % of eggs) versus experimentally manipulated turbid water (72.2 % at 5.5 NTU).

In addition to physiological effects, high suspended sediment concentrations may also affect reproductive behaviors. Sutherland (2007) exposed eggs of the crevice spawning minnow the Whitetail Shiner (*Cyprinella galactura*) to pulsed suspended sediments with concentrations of 0, 25, 50, 100, and 500 ppm. Spawning effort was affected at concentrations as low as 50 ppm and did not occur in four of the seven high concentration replicates. Based on the developmental state of the eggs it was also clear that reproduction was substantially delayed in the 100 and 500 ppm treatments.

Adverse impacts to reproduction will be avoided, to some degree, through the timing of the Proposed Action. Both the dam notch and complete dam demolition would occur in the fall, months before spring reproduction. Sediment released from construction activities and the subsequent winter storm events would occur at a time when eggs are not present in the Sandusky River. Sediment mobilized in spring storm events could possibly increase egg exposure to elevated sediment concentrations. The eggs of at least one species (Walleye) have demonstrated a fairly robust tolerance for elevated suspended solids concentrations and should not be affected by concentrations expected from the Proposed Action. Behavioral modification may be expected in some species as a result of high concentrations associated with storm events. However, storm generated concentrations are already high under the base line scenario and fish species in the project area and behavioral responses exhibited at present should not differ substantially from those expected with the Proposed Action. It is also important to recognize that impacts from the dam are temporary. Beneficial elements of the Proposed Action, such as increased fish passage, would be more permanent. Walleye, in particular, would benefit from an additional 22 miles of spawning habitat.

Changes to structural habitat quality

Major changes to structural habitat quality are not anticipated downstream of the dam. High gradient bedrock and cobble reaches, due to their high transport capacity, would experience little change in substrate composition or embeddedness as a result of the dam removal. Current Walleye spawning habitat should not be affected by sediment releases (Stantec 2011). In fact, these areas may be enhanced through restoration of coarse sediment supply from the upper watershed. It is unlikely that coarse sediments have passed below the dam in more than

100 years. Low-gradient reaches may experience aggradation associated with the sediment wedge described above. The spatial and temporal extent of this impact is currently unknown. However, adverse effects are expected to be short-term and temporary. Prior dam removal studies suggest that the duration of impact could be one to three years.

Restoration response

Although fish communities can be adversely impacted by increased turbidity after a dam removal, the impacts are temporary. Maloney et al. (2008) studied the impacts of a dam removal on the fish community in the Fox River in Illinois. Three years after the dam removal, the fish community shifted toward, but had not completely become, lotic. Former impoundments often lack instream structures (i.e. woody debris and boulders) and spawning habitat (coarser substrates, aquatic macrophytes) following dam removal. Kanehl et al. (1997) stated that it may take as long as five years for a former impoundment to show improvements in recovery following a dam removal. As impoundments revert to a free flowing state, additional restoration practices may be required to hasten the shift from a lentic to lotic habitat system (Maloney et al. 2008).

Studies of riverine impoundments typically document simplified fish communities as a result of poor habitat conditions (e.g., sediment anoxia, absence of spawning habitat, depressed macroinvertebrate production, and poor water quality; OEPA 2010a, OEPA 2010b). After the Woolen Mills Dam on the Milwaukee River in Wisconsin was removed, Smallmouth Bass increased in the stream reach due to the reintroduction of coarser sediments to the river (Kanehl et al. 1997; Nelson and Pajak 1990). Furthermore, more Smallmouth Bass spawning habitat became available following the dam removal (Staggs et al. 1995). Burroughs et al. (2010) examined the impacts of the removal of the Stronach Dam on the fish assemblage of the Pine River in Michigan. After the removal, eight fish species formerly restricted to areas downstream of the dam migrated to newly accessible areas upstream of the dam. Eighteen of the 25 species evaluated showed an increase in number after the removal, suggesting that dam removal may increase habitat availability for riverine fishes (Burroughs et al. 2010). Stantec (2012b) observed that the biomass of sensitive intolerant species, such as River Redhorse and Black Redhorse, increased by an order of magnitude only two years after removal of Englewood Dam on the Stillwater River in Ohio.

CONCLUSIONS

CHANNEL RESPONSE

- Demolition of Ballville Dam would instigate a series of channel adjustments that would export sediment currently stored in the impoundment to downstream reaches over 14 to 24 months.
- Most sediment export would occur within the first year following complete demolition of Ballville Dam but could take longer if the magnitude of seasonal storms is small and streamflows are insufficient to transport material.

NAVIGATION

- A sediment wedge is expected to form somewhere within the City of Fremont near the transition of the steep bedrock reach and the lower gradient part of the Sandusky River.
- Sediment transport models indicate that the maximum height of aggraded sediment would be approximately 2.5 ft in the leveed reach but that typical depths would be less than 1.0 ft.
- The effects of the sediment release would gradually diminish over time as sediment is mobilized and redistributed by storm events or would immediately be diminished if a larger storm occurs shortly after dam removal.
- Motorized watercraft navigation may be temporarily impaired while the channel adjustments progress.

FLOOD CONVEYANCE AND CAPACITY

- Hydraulic models suggest that sediment aggradation could cause a water surface elevation increase at flood flows of less than 0.1 ft.
- It is expected that the City will be protected from this increase because of (1) the flood capacity associated with the freeboard of the levee system, and (2) the high sediment transport capacity of river during high flow events.

WATER QUALITY

- Suspended sediment concentrations observed at other dam removal projects vary considerably depending on site specific conditions. In comparison to other projects reviewed, Ballville Dam:
    - Currently stores a higher volume and proportion of easily mobilized fine grained sediments.
    - Is located on a large river system with tremendous capacity to transport sediment.
- High suspended solids concentrations are largely produced by storm events and return to normal levels quickly with decreasing discharge.
- Measureable effects of dam removal activities dissipate within 6 – 12 miles of the dam.

AQUATIC BIOTA

- Fish, mussels, and other aquatic organisms are adapted to short-term elevated suspended solids concentrations
- Some aquatic community metrics (e.g., fish passage) recover quickly (weeks to months) from disturbances associated with dam removal while others (e.g., riparian vegetation) may require months to years to fully recover (Doyle et al. 2005)

DISCUSSION

Ballville Dam began to accumulate and store sediment from the Sandusky River watershed soon after its completion in 1912. It is currently believed to be in “equilibrium” and exports as much material as is received from the watershed. Approximately 840,000 CY of sediment are currently stored in the Ballville Dam Impoundment. Dredging and disposal of this material would be cost prohibitive with complete removal estimated at $45,000,000 (Stantec 2013). Demolition of Ballville Dam will release some proportion of the sediment to the lower part of the Sandusky River. While the general physical processes that cause sediment export from demolished dams are understood in a qualitative sense, there are no quantitative models that accurately predict total volumes to be exported, location of sediment deposits, and duration of impact. Fate and transport models can be useful, however, in helping to define the domain of the expected response and to understand the limits of extreme or worst case scenarios. Stantec (2011) modeled instantaneous transport of the entire volume of sediment in a single event. These models suggest that no more than 2.5 feet of sediment aggradation would occur in any single location and typical depths would be closer to 1.0 feet. Further, flood elevations would increase less than 0.1 feet. In reality, not all of the sediment would be exported from the impoundment nor would it happen in a single event. Instead sediment export would occur episodically in conjunction with storm generated steamflows over the course of several months or even years. The Proposed Action further seeks to minimize the impacts of sediment aggradation below Ballville Dam by 1) constraining the volume of sediment released in the first year by notching the dam, 2) spreading the timing of releases over a longer period to allow for redistribution of material released in year one during year two, 3) aggressive planting of exposed sediment flats to minimize the volume of material exported. In light of this information it is reasonable to conclude that adverse impacts to navigation and flood conveyance and capacity from the Proposed Action, if they occur at all, would be of limited magnitude and duration.

It is probable that demolition of Ballville Dam and the subsequent increase in sediment load would represent a disturbance to aquatic ecosystems and biota downstream of the dam. Due to uncertainties regarding the magnitude, duration, and rate of transport associated with the physical response of the river to increased sediment load, it is difficult to predict the ecological response. Based on our current understanding of the physical processes at work, the disturbances would be temporary and potentially within the current range of variation for this system. Nonetheless, many studies report declines in community metrics in the years following dam removal (e.g., Sethi 2004, Maloney et al. 2008) although notable exceptions exist (Heise et al. 2013). In either case evidence from longer term studies suggest that ecosystem components recover from the episodic disturbance caused by dam removal. Doyle et al. (2005) propose a conceptual model suggesting that some organisms and/or populations would likely recover quickly from dam removal (e.g., aquatic insects) while others would potentially require longer (e.g., riparian vegetation). This model is in general agreement with a wider body of literature on the topic of ecological recovery from anthropogenic disturbances. Borja et al. (2010) reviewed over 50 case studies of the recovery of estuarine and coastal ecosystems from various types of environmental degradation including oil spills, disposal of sewage sludge and mine tailings, land reclamation, and long term wastewater discharges. An important conclusion from this work was that some reduction of the stressor or disturbance agent was necessary for recovery to begin but the reduction need not be complete for some recovery to progress. In the case of Ballville Dam, the primary stressor is the export of sediment currently stored in the impoundment to downstream reaches. As described in prior sections of this document, sediment deposits will degrade and redistribute over time. Although there are few comprehensive studies available on this topic, those that are available suggest that this happens quickly over the course of a few years. After only two years, the sediment wedge below the former Marmot Dam site contained only 25 percent of the original stored volume.

Of course the Proposed Action must be considered not only in terms of potential adverse impacts but also in terms of potential benefits. Removal of the Ballville Dam is one of those rare restoration projects that would deliver ecological benefits at local, regional, and international scales. At the local level, elimination of artificially-created lacustrine habitat associated with the dam impoundment will benefit the riverine ecosystem and continuity of aquatic habitat. Improvements to the structural and functional elements of aquatic habitat in the impounded reach of the Sandusky River will yield substantial improvements to Aquatic Life Uses. At the regional scale, an additional 22 miles of the Sandusky River will be opened to migratory fish species including Walleye, White Bass, and the State-threatened Greater Redhorse. Riverine walleye populations in the Sandusky system are currently constrained by access to approximately 20 acres of spawning habitat. Access to the upper river will increase available spawning habitat to approximately 300 acres. The supply of coarse-grained sediments may also be restored to sediment starved reaches downstream of the dam potentially replenishing critical but diminishing spawning habitats. Increased reproductive success at the regional scale will yield benefits far beyond the project site as people throughout Lake Erie from the United States and Canada will be able to catch fish that originated in the Sandusky River. In contrast to the wide spread and long lasting benefits derived from the Proposed Action, adverse impacts are expected to be short term and temporary.

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7- Ballville Dam Flood Storage Capacity Memorandum

Memo

Stantec

To:	Brian Elkington Fisheries Coordinator U.S. Fish and Wildlife Service	From:	Scott Peyton Senior Principal Stantec Consulting Services Inc.
File:	175631016	Date:	July 24, 2012

Reference: Ballville Dam Flood Storage Capacity

Goal: To assess the use of the Ballville Dam and associated impoundment for flood storage.

Objectives:

- Provide a background and description of the dam and impoundment
- Describe the design function of the dam and impoundment
- Describe physical setting including hydrology, flooding, and geomorphology
- Describe the current hydrology (inflow/outflow) of the Ballville Impoundment
- Conclude whether the Ballville Dam and impoundment can be considered for flood control

Background

The dam was originally built by the Fremont Power and Light Company, which later became the Ohio Power Company. The dam was abandoned as a hydroelectric facility in the early 1900's because the seasonal flow of the river was insufficient to meet the power generating requirements of the plant. The company built a steam power plant to supplement the output of the hydroelectric plant in 1916. The steam power plant closed in 1929 but was reactivated briefly during World War II to supplement the region's power supply. The steam power plant was demolished in 1954. The City of Fremont (City) bought the land and facilities in 1959 and sealed and removed the penstock to re-purpose the dam as a raw water source for the City (Terpstra et al. 2011).

The Ballville Dam was built on the Sandusky River between 1911 and 1913. It is located in the Township of Ballville, upstream of the City. The dam is approximately 18 river miles upstream of Lake Erie. The Dam is classified by the Ohio Department of Natural Resources (ODNR) as a Class I structure; the highest hazard rating due to the probable loss of life if the dam were to fail during a flood event.

The Ballville Dam is approximately 407 feet long and 34.4 feet high. It is composed of left and right spillways on either side of a non-overflow section. The right spillway, facing downstream, is 228 feet in length and has a crest elevation of 623.82 feet above mean sea level; the left spillway is 86.5 feet long and has a crest elevation of 624.24 feet above mean sea level; and the non-overflow section is 92.5 feet long with a crest elevation of 633.82 feet above mean sea level.

The non-overflow section has a penstock[1], six sluice gates[2], and a water intake. The penstock opening and four of the six sluice gates have been permanently sealed, and the operability of the remaining two sluice gates is unknown. The water intake consists of two 48-inch pipes, with another 48-inch concrete pipe connecting the intake to the carbon feed building on the left abutment. The left abutment has another intake and sealed penstock. Water is carried to the treatment plant via a 42-inch pre-stressed concrete pipe. A concrete sea wall, with a top width of 1.5 feet and top elevation of 636.7 feet above mean sea level, extends approximately 702 feet upstream from the left abutment.

The impounded length of the Sandusky River extends upstream from the Ballville Dam approximately 2.1 miles (3.4 km). The U.S. Army Corps of Engineers (USACE) have estimated the surface area of the impoundment to be approximately 89.3 acres at low flow. There are a number of residential properties along the banks of the Sandusky River with views of the impoundment.

The impoundment has been accumulating and storing sediment since its completion in 1913. It appears that the dam is approaching or has reached an equilibrium state where a very little volume of new material is stored despite the high volumes of sediment delivered from the watershed. Evans et al. (2002) estimated that the storage capacity of the impoundment has decreased 78 percent due to sedimentation. The trapping efficiency of the dam is estimated to be approximately four percent based on survey data from the previous decade (Evans et al. 2002). Estimates of sediment depths range from 11 feet near the water intake at the dam to over 20 feet near some outer margins. Photos and multiple bathymetric surveys indicate that a partially defined channel has remained within the impoundment sediment. An island within the impoundment has formed over the last 30 years as sediment has continued to accumulate along the inner portion of the river bend upstream of the dam. The formation of the island has promoted further deposition on the south shore downstream of the island.

Only one documented drawdown has occurred since the dam's use was converted from electric generation to water supply. The drawdown occurred in 1969 to allow for repairs and modifications to the dam, intake, and sluice systems.

Dam Functionality

The Ballville Dam was constructed as a run-of-river hydro-electric facility. Operational functions of dams, in general, can be divided into two groups: storage and run-of-river. A storage dam typically has a large amount of hydraulic pressure, large available storage volume capacity, long hydraulic residence time (amount of time water stays in impoundment), and control over the rate at which water is released from the impoundment. In contrast, a run-of-river dam generally has a small amount of hydraulic pressure, small amount of storage capacity, short hydraulic residence time, and little or no control over the rate at which water is released from the impoundment (Poff and Hart 2002). In short, run-of-river outflow nearly equals the amount of

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[1] An enclosed pipe that delivers water to hydraulic turbines.

[2] A gate located at or near the stream bed that allows water and sediment to pass from upstream of the dam to downstream. The structures are common features of dams and are typically used to draw the pool down for maintenance

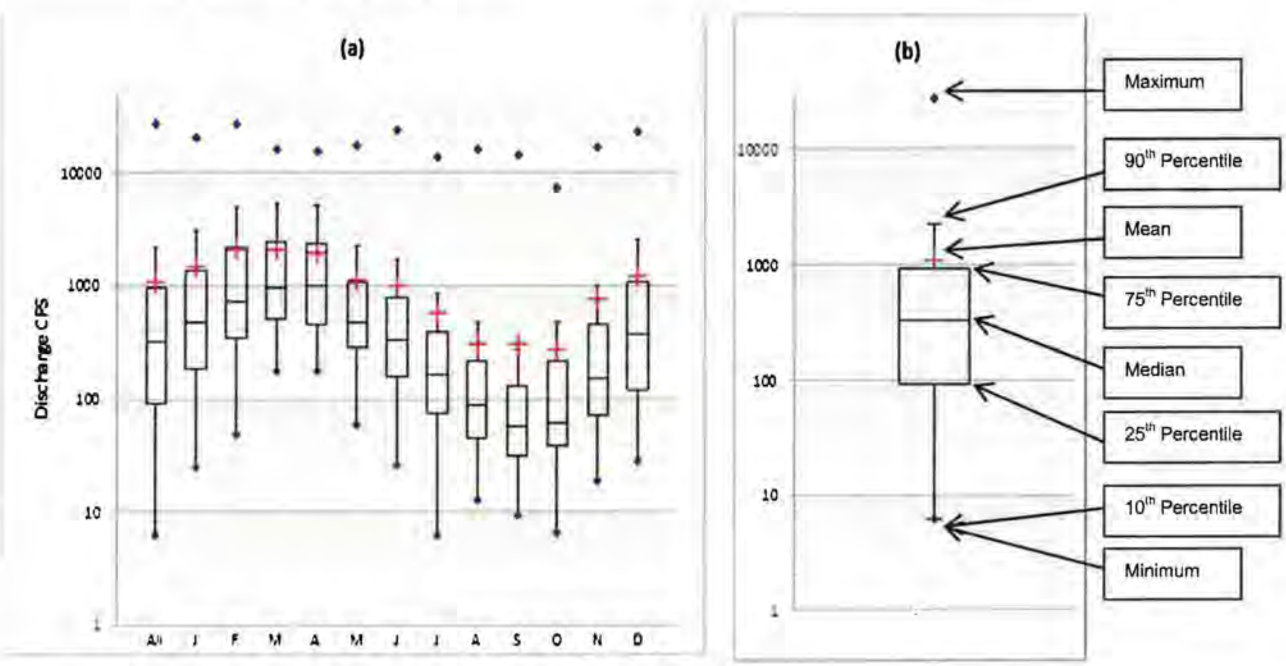
inflow. While impoundment levels may vary by a few feet during normal operations to provide a pool for water withdrawal, they typically are not designed for water storage[3].

Physical Setting

The United States Geological Survey (USGS) operates a gage (04198000) located approximately 2.2 miles upstream from the dam. The contributing drainage area at the gage is reported as 1,251 square miles. Discharge records, reported in cubic feet per second (cfs), span the period from water year 1924 to the present, except for 1936-1938. Suspended sediment records, reported as milligrams per liter (mg/l) and tons per day (tn/dy), span the period of water years 1951-1956 and 1979-2002 (Stantec 2011).

Hydrology. Precipitation in Sandusky County averages 34 inches per year (1960-1990). The average mean annual discharge over the period of record is 1,064 cfs, with a maximum and minimum mean annual discharge of 2,167 cfs in 1984 and 275 cfs in 1934, respectively. The highest mean daily discharge is 36,000 cfs (1978) and the lowest is 5 cfs (1963). Typically, the highest flows are observed in February, March, and April and the lowest in August, September, and October (see Figure 1). Flows of 10,000 cfs or more may occur in any month of the year although 90 percent of the flows in the summer months are less than 1,000 cfs (Figure 1; see Stantec 2011).

Figure 1. (a) Maximum, minimum, and average values of mean monthly discharge, (b) legend for this box plot



[3]Source: http://www.usbr.gov/pn/about/dams/index.html

Flooding. Floods in Sandusky County are historically common. According to available records, flood events were recorded in 1821, 1847, 1860, 1863, 1879, 1883, 1884, 1904, 1910, 1912, 1937, 1959, and 1963 (see Stantec 2011), and many of these caused noteworthy damage within the City. The flood of record occurred in 1913 with an estimated peak discharge of 63,500 cfs. Floodwalls constructed by the USACE in 1972 have limited flood impacts to the City in subsequent years and are designed to contain discharges exceeding 50,000 cfs, with limited freeboard. Table 1 presents peak flood discharges for selected recurrence intervals determined from an analysis of available USGS data.

Table 1. Flood Frequency Analysis*

Recurrence Interval (years)	Peak Discharge (cfs)
1.01	6,170
1.5	12,710
2	15,520
5	20,990
10	24,380
50	31,410
100	34,200

Based on annual peak discharge as reported by USGS

It should be noted that many historical flood events were due to ice jams in the river downstream of Fremont. Although storm flooding has been documented, it is the combined influence of storms and ice floes[4] that have the greatest potential for flood damage. A full account of ice jam and related flooding research in Fremont was performed by the Cold Regions Research and Engineering Laboratory (CRREL) of the US Army Engineer Research and Development Center and published in two reports:

- Impact of the Ballville Dam on Ice Jams in Fremont, Ohio (2008); and
- Removal of the Ballville Dam on the Sandusky River at Fremont, Ohio: Ice-Hydraulic Analysis (2011).

Fremont is located near the boundary of lake level influence on the Sandusky River. The low gradient, low energy section of the river from the City to the Sandusky Bay facilitates the accumulation of ice and formation of ice jams. Surface ice, typically formed in flat sections of the river, and frazil ice, typically formed in steep sections of the river, originate upstream and become trapped as the river transitions into the low-gradient lake influenced areas. As ice accumulates, upstream water levels may be elevated, increasing the chance of flood damage.

These same processes at work in the lower river are present in the Ballville Dam Impoundment, although on a smaller scale. The surface of the impoundment freezes due to the slow moving water and creates a barrier to the downstream floe of ice. The jam point is located approximately 1.7 miles upstream from the dam approximately where River Road (CR 132) begins to run parallel to the river.

[4] A mass or sheet of floating ice.

Six major ice jam related flood events have caused damage to the City. Four events, in 1833, 1843, 1883, and 1904, occurred before the Ballville Dam was completed in 1913. Two events, in 1959 and 1963, occurred after the dam was built but before the flood walls were constructed in 1972. No ice related flood events have caused damage in Fremont since the flood walls were built. Two large floods in 1978 (36,000 cfs) and 2007 (22,300 cfs) occurred when there was potential for ice jams and ice jamming was recorded upstream of Ballville Dam without reported flood damage in Fremont (USACE - CRREL 2008 and 2011). Review of the Ballville Dam as it relates to ice floes is outside the scope of this document.

Geomorphology

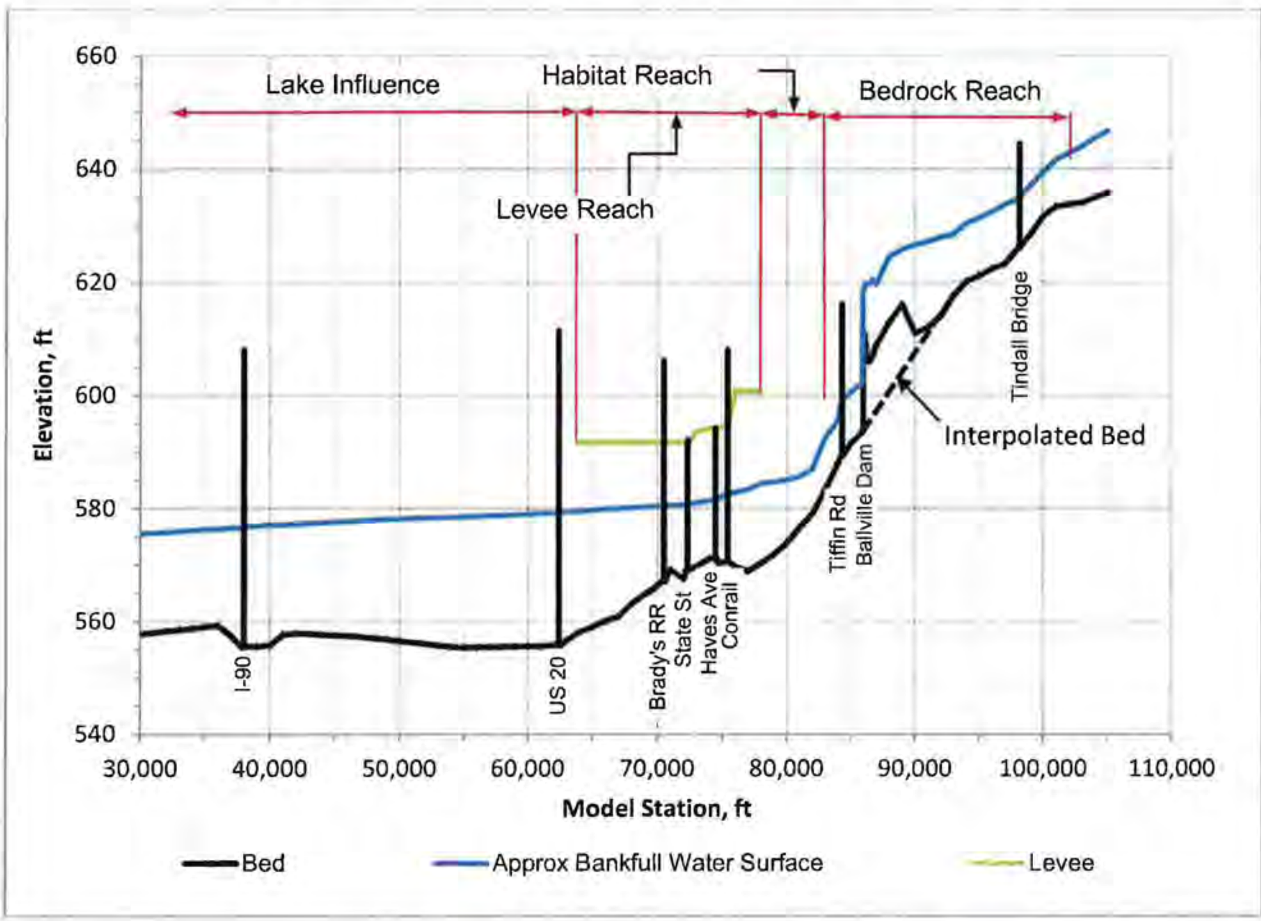
The Sandusky River begins near the edge of the Glaciated Allegheny Plateaus physiographic region in Crawford County, Ohio and passes through the Till and Lake Plains regions on its way to Sandusky Bay and Lake Erie. Changes in river characteristics can be seen as it passes numerous historic lake and glacial boundaries. River meanders are typically a function of till plain irregularities acting as migration boundaries south of Tiffin, which lies on the border of the Till and Lake Plains. As the river enters the Lake Plains region, meanders become larger as the floodplains begin to widen. The river is only slightly to moderately entrenched, as bed incision has been impeded by substantial areas of limestone and dolomite bedrock. Downstream of the City, meanders become more pronounced and irregular as the newer floodplains expand greatly near the bay (Stantec 2011).

Within the vicinity of the Ballville Dam and Impoundment, channel characteristics and slopes vary (Figure 2). Upstream of the impoundment, the channel is dominated by bedrock substrate with some interstitial gravel and cobble. The bedrock has limited channel incision, creating wide cross sections with width to depth ratios (W/D) between 50 and 60. The channel is only slightly entrenched and floodplain access is generally good. Slopes are relatively steep (0.002 ft/ft) in the bedrock sections which yield high velocities. The same characteristics exist immediately below the dam; however, at this point the channel is more entrenched. This condition changes as the stream gains distance past the Tiffin Road Bridge constriction and becomes less laterally confined.

As the river passes the Tiffin Road Bridge, gravel and cobble material become more prevalent in the substrate. Frequent side and mid-channel bars composed of these materials are observed from just past the bridge down to the large left-hand bend adjacent to the River Cliff Golf Course. Bedrock still dominates as grade control through this reach, but increased water depths are seen locally, such as near the old hydroelectric facility. Field survey indicated a hydraulic slope of 0.003 ft/ft. Just downstream of the decommissioned hydroelectric generating facility, the valley expands considerably. The main channel of the river narrows to approximately half of the width observed upstream of the dam impoundment, as flow is diverted to side channels in forested areas on both banks. The inside of the left-hand bend is also comprised of frequent divergent channels. These channels are less stable and are formed and altered due to the presence of massive amounts of driftwood and debris dropped here during flood events.

Immediately past the left-hand bend near the golf course, the river changes characteristics substantially. This geomorphic reach extends from near the golf course to the north side of Fremont. Its most prominent feature is the levee and flood wall system finished in 1972, which laterally confines the river and forms an entrenched channel. Except for a narrow section adjacent to Roger Young Park, the base-flow channel width is generally 350 to 400 feet. Depth ranges throughout the reach, with the deepest portion at the narrow levee constriction. The flood walls in this reach eliminate floodplain access and are designed to protect against a 50,000 cfs flood event with some freeboard. While the river bed slope is relatively high, bankfull water surface slope (0.0008 ft/ft) is greatly reduced due to backwater effects from the lake-level impacts downstream. Substrates range from bedrock to clay size particles, with a predominance of sand and fine gravel.

Figure 2. Profile of Sandusky River (taken from Stantec 2011)



The remainder of the river downstream to the Bay is flat (0.0002 ft/ft). Channel width increases in the direction of the bay, with distances between the banks frequently reaching greater than 1,000 feet near the mouth. There is floodplain connectivity in the majority of the reach except where dikes have been built. As the river nears the transition to Muddy Creek Bay, it begins to resemble a marsh ecosystem. The heavy suspended sediment load from the watershed begins to settle out of the water column and deposition of sediment is heavy in this area. There is less channel definition in this area with widespread deposition of fine particles creating frequent islands. Dikes around private lands at the mouth provide some physical definition between marsh and active channel.

Flood Storage Analysis Methodology

The following flood storage analysis was performed to understand the capacity of the Ballville Dam and impoundment. Three key components are necessary to perform this analysis: 1) outflow, 2) inflow, and 3) storage. Impoundments, in general, provide water storage up to a maximum level; the level defined by the elevation where the water crests and spills over the Ballville Dam. The storage volume when divided by the rate of inflow provides an estimated time to reach storage capacity. The following equation is used to estimate the time needed for capacity to be reached.

$$\frac{Storage\ Volume\ (ft^3)}{Inflow\ (\frac{ft^3}{sec})} = Time\ (sec)$$

Outflow. Outflow is the amount of water discharged from the sluice gates. This analysis assumes the six (6) sluice gates are operational and left permanently open. Discharge from the gates is dependent upon the water level behind the dam. As the water level increases, pressure builds up behind the gate, leading to higher discharge. To simplify this analysis, however, the assumption of a constant outflow discharge equal to a value associated with a water level even with the crests of the spillways (i.e. 624.24 ft above mean sea level) is used. Therefore, discharge through the sluice gates is estimated to be approximately 1,950 cfs. This conservative assumption was used in the analysis as a means to slow the rate at which the empty impoundment would fill.

At the point when water crests the dam and flaws over the spillway (i.e. capacity) water inflow roughly equals water outflow (i.e. 1,000 ft^3/sec inflow = 1,000 ft^3/sec inflow). Therefore, consideration of both inflow and outflow is critical for a dam and impoundment to be used as flood storage during various flood events. Storage is estimated by the following equation.

$$inflow\left(\frac{ft^3}{sec}\right) - outflow\left(\frac{ft^3}{sec}\right) = \frac{\Delta\,Storage}{\Delta\,Time}\left(\frac{ft^3}{sec}\right)$$

Inflow. Inflow is the amount of water received by the impoundment. This analysis evaluates flood events at return intervals of 1, 2, 100, and 500 years (approximately 6,000; 15,000; 40,000; and 50,000 cfs peak annual discharges, respectively). For reference, a 1-year event typically does not leave the banks of a river; a 2-year event typically leaves the channel and inundates the adjacent floodplain; a 100-year event is the standard for Federal Emergency Management Agency (FEMA) Flood Insurance Rate Mapping; and a 500-year event was the design flow for the floodwalls in Fremont.

USGS gage data at Tindall Bridge indicate annual peak flow values are very similar to the daily means on those days when the annual peaks were recorded. This suggests the peak (cfs) of flood events can last for 24 hours or greater. Inflow is simplified as a constant rather than a typical storm hydrograph that would be highly variable, but less than the constant assumed. A typical hydrograph would show the impoundment being filled prior to the arrival of peak discharge to the impoundment.

Storage. Storage is the volume of water that can be stored behind the Ballville Dam before cresting the spillways. This analysis assumes an estimated 840,000 cubic yards (CY) of sediment has been dredged from the impoundment. This assumption was intended to provide the maximum amount of storage possible under the current configuration. Water volume is the current, pre-dredged, water volume capable of being stored in the impoundment and is estimated to be approximately 1 million CY. When added together the impoundment has an estimated storage volume of 1,840,000 CY or 49,680,000 cubic feet (ft^3).

Calculation Results

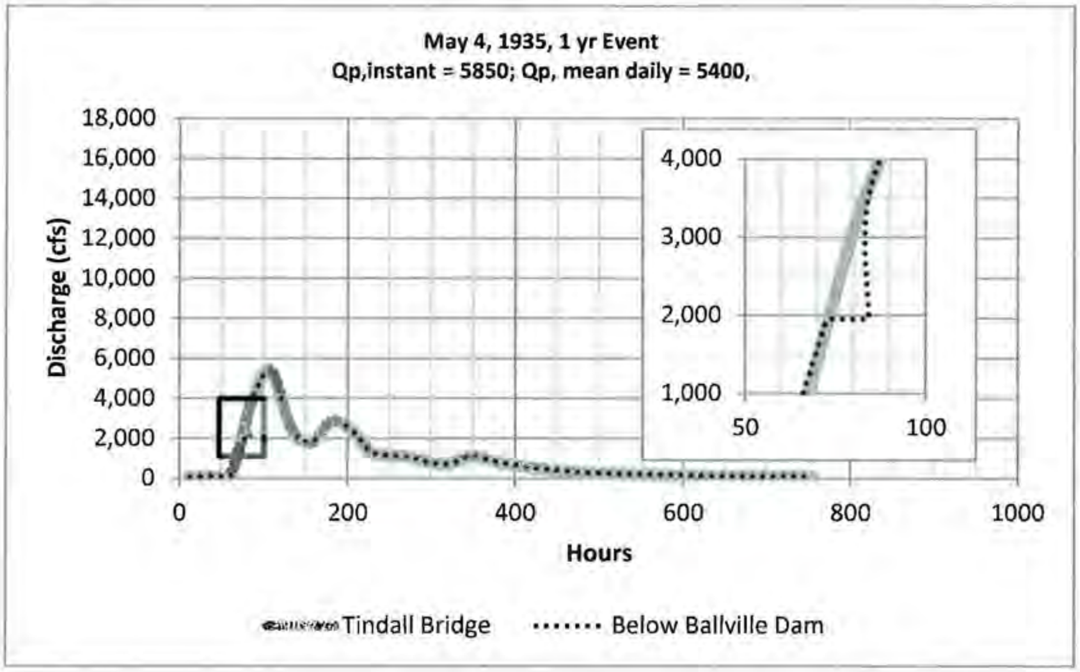
1-Year Event:

During a 1-year flood event, the inflow to the impoundment is expected to be approximately 6,000 ft^3/sec. As mentioned previously, sluice gate outflow is assumed to be 1,950 ft^3/sec, resulting in an inflow rate of excess water equal to 4,050 ft^3/sec. When dividing the storage capacity of the impoundment by the outflow, it is calculated that it would take approximately 3.4 hours to fill the impoundment to the spillway level.

$$\frac{49{,}680{,}000\ (\mathrm{ft}^3)}{4{,}050\ (\frac{ft^3}{sec})} = 12{,}267\ (\mathrm{sec})/3{,}600\left(\frac{sec}{hr}\right) = 3.4\ hours$$

The hydrograph for a typical 1-year event (Figure 3) shows that the peak discharge and time to peak at the USGS gage and at the Ballville Dam are effectively equal due to the dam's run-of-river functionality.

Figure 3. Hydrograph for typical 1-year event for Sandusky River at Ballville Dam project area. The dashed line in the inset box shows the period where the impoundment is storing water.



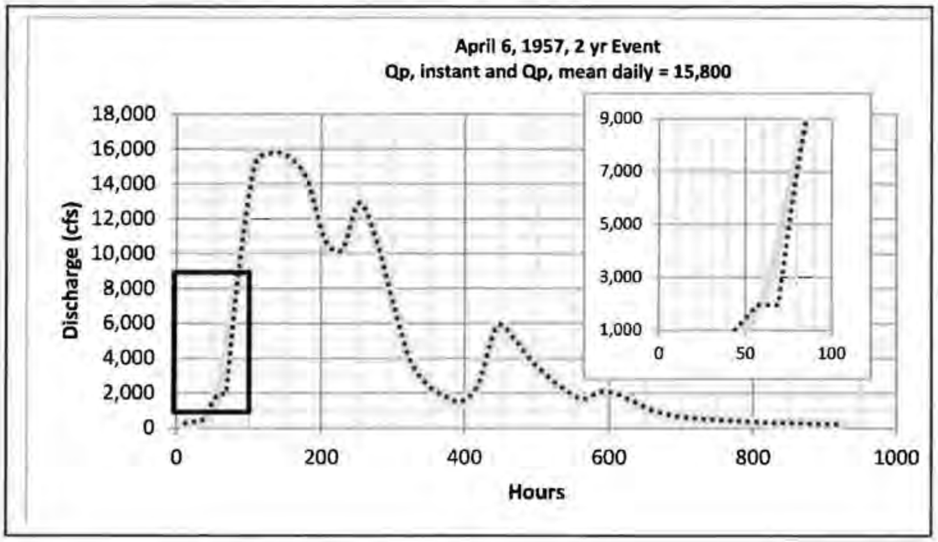
2-Year Event:

During a 2-year flood event, the inflow to the impoundment is expected to be approximately 15,000 ft^3/sec. As mentioned previously, sluice gate outflow is assumed to be 1,950 ft^3/sec, resulting in a flow rate of excess water equal to 13,050 ft^3/sec. When dividing the storage capacity of the impoundment by the outflow rate from the sluice gates, it is calculated that it would take approximately 1.1 hours to fill the impoundment to the spillway level.

$$\frac{49{,}680{,}000\ (ft^3)}{13{,}050\ (\frac{ft^3}{sec})} = 3{,}806\ (sec) / \ 3{,}600(\tfrac{sec}{hr}) \ = 1.1\ hours$$

The hydrograph for a typical 2-year event (Figure 4) shows that the peak discharge and time to peak at the USGS gage and at the Ballville Dam are effectively equal due to the dam's run-of-river functionality. This is true for various fluctuations during the event as well.

Figure 4. Hydrograph for typical 2-year event for Sandusky River at Ballville Dam project area. The dashed line in the inset box shows the period where the impoundment is storing water.



100-Year Event[5]:

During a 100-year flood event, the inflow to the impoundment is expected to be approximately 34,200 ft^3/sec. As mentioned previously, sluice gate outflow is assumed to be 1,950 ft^3/sec, resulting in a flow rate of excess water equal to 32,250 ft^3/sec. When dividing the storage capacity of the impoundment by the outflow rate from the sluice gates, it is calculated that it would take approximately 0.4 hours to fill the impoundment to the spillway level.

$$\frac{49{,}680{,}000\ (ft^3)}{32{,}250\ (\frac{ft^3}{sec})} = 1{,}540(\text{sec})/3{,}600\left(\frac{sec}{hr}\right) = 0.4\ hours$$

500-Year Event:

During a 500-year flood event, the inflow to the impoundment is expected to be approximately 50,000 ft^3/sec. As mentioned previously, sluice gate outflow is assumed to be 1,950 ft^3/sec, resulting in a flow rate of excess water equal to 48,050 ft^3/sec. When dividing the storage capacity of the impoundment by the outflow rate from the sluice gates, it is calculated that it would take approximately 0.3 hours to fill the impoundment to the spillway level.

[5] No hydrograph is included for the 100 and 500 year event as they would also depict a similar hydrograph as the 1- and 2-year events with increased volumes.

$$\frac{49{,}680{,}000\ (ft^3)}{48{,}050\ (\frac{ft^3}{sec})} = 1{,}033(\text{sec})/3{,}600\left(\frac{sec}{hr}\right) = 0.3\ hours$$

Conclusions

The goal of this memo was to assess the flood storage ability of the Ballville Dam and the associated impoundment. The Ballville Dam was operational in 1913 and originally designed to function as a run-of-river hydro-electric generation facility and not as a flood storage impoundment.

The flood levees within the City of Fremont (downstream of the Ballville Dam) are currently designed to convey a 500-year flood event at approximately 50,000 cfs without overtopping. Analysis of available data indicates that the Ballville Dam was not designed to provide flood storage. At a 500-year flood flow rate, a completely empty impoundment (a very conservative assumption) would fill to capacity in approximately 18 minutes. In order for the Ballville Dam to function as a flood storage impoundment, it would need to store flood flows for at least the duration of large storm events, typically 24 to 48 hours. This analysis shows that the Ballville Dam and Impoundment provide insignificant downstream hydrograph attenuation and added flood protection. Therefore, even using very conservative assumptions, the use of Ballville Dam for flood storage is not a viable option.

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STANTEC CONSULTING SERVICES INC.

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Senior Principal

/lfb

8- Fish Passage Structure Memorandum

Memo

Stantec

To:	Brian Elkington, Fisheries Coordinator U.S. Fish and Wildlife Service	From:	Michael Chelminski, P.E. Jeff Brown, Sr. Env. Scientist Cody Fleece, Sr. Env. Scientist Stantec Consulting Services Inc.
File:	175631016	Date:	May 7, 2013

Reference: Ballville Dam EIS Alternative 2 –Fish Elevator

Purpose of this Memo

The purpose of this memo is to provide a conceptual design for a fish elevator (also called a "fish lift") at the Ballville Dam as an alternate way to provide for fish passage on the Sandusky River. The intent of this memo is to provide information for understanding how a fish elevator for upstream fish passage at Ballville Dam may be constructed, operated, and maintained.

Background

The U.S. Fish and Wildlife Service (USFWS) is the lead agency for developing a Draft Environmental Impact Statement (DEIS) for the Ballville Dam Removal Project based on the funding commitment of $2 million from the Great Lakes Restoration Initiative (GLRI) through the Great Lakes Fish and Wildlife Restoration Act (Act)(16 U.S.C. 941 §4321 et seq.). The Act authorizes the USFWS to work in partnership with States, Tribes, and other Federal agencies for the restoration of fish and wildlife resources in the Great Lakes Basin.

Issuance of funding under the Act constitutes a discretionary federal action by the USFWS and is thus subject to the National Environmental Policy Act (NEPA). As the lead agency, the USFWS has determined that an Environmental Impact Statement (EIS) is appropriate for meeting compliance with NEPA. The NEPA process requires that federal agencies integrate an interdisciplinary environmental review process that evaluates a range of alternatives, including the other feasible action alternatives, as part of the decision-making process. The Fish Elevator Alternative was developed for evaluation as an alternative for allowing fish movement upstream of the dam without dam removal.

Overview of Fish Elevator Systems

Fish elevator systems have the potential to provide for upstream passage of target fish species and/or life stages that may not be provided upstream-passage for "flow-through" (e.g., vertical slot, Denil, pool-and-weir) fishpasses, as swimming speeds are not relevant to the actual vertical transport of the fish. Constraints on upstream passage (lifting) are therefore limited to having fish enter and safely exit the lift. Fish lifts may therefore be appropriate for fish that have relatively low swimming speeds, such as walleye, or relatively large fish, such as sturgeon, which may not successfully pass upstream through flow-through fishpasses.

The operational regime of a fish elevator system is generally comprised of the following components:

1. Attraction of fish into the fishpass inlet (hydraulic exit);
2. Guidance of fish into a trap system;
3. Closure of the trap system;
4. Lifting of the trap;
5. Discharge of the fish into a sorting system[1];
6. Release of target fish species into an outlet channel; and
7. Discharge of fish into the upstream environment.

The fundamental component of a fish elevator system is a means for trapping target fish species, and is typically locating in the vicinity of the downstream end of the structure around which upstream passage is desired. The entrance of the trap system must be located in an area that is readily accessible to the target fish species during the target seasonal migration period(s), and performs in a manner that is similar to a volitional fish passage system.

Criteria that need to be considered in the development of a suitable entrance into the trap system include its location, geometry, attraction flow, and conditions in the adjacent reach of the river. The trap entrance must be in a location that is accessible to the target fish species during seasonal flows in the Sandusky River. It should be assumed that the fish elevator would be designed to function at flows that are less than the noted 75th percentile exceedence flow (156 cfs) as upstream passage may be critically important during low flow conditions.

Guiding fish into the trap system requires that the geometry and location of the facility entrance function over a range of flows (e.g., from 150 to 2,500 cfs). The vertical extent of the entrance must be well below (e.g., at least 3 to 4 feet [ft]) the elevation of the normal tailwater at the minimum flow, and may need to extend to the elevation of the bottom of the adjacent streambed if the target fish species preferentially move along the bottom. Augmentation of flow would be necessary to provide for suitable attraction flow, and would likely be variable, with increased attraction flow during higher flows in the river. If conditions in the immediate vicinity of the entrance are very turbulent, the design of the entrance structure may need to incorporate protrusions into the tailrace that provide for hydraulic conditions that allow for fish to move upstream in the tailrace to the trap entrance.

Flow augmentation can be provided using a gravity feed from the upstream impoundment, and would require introduction of flow in the vicinity of the facility entrance and introduction of flow

[1] The presence of undesirable introduced species in the Great Lakes, such as sea lamprey, likely necessitates inclusion of a sorting facility for removal of undesirable species to prevent introduction upstream from Ballville Dam.

through the trap system. Each system would need control valves to manage appropriate flow speeds at the entrance and approach to the trap.

The trap system could operate on a regular basis (e.g., every half-hour) or on an "on-demand" basis based on visual observation of fish in the trap or other method(s). The trap system could be comprised of a positive gate structure that would be closed prior to lifting or a passive system, such as a fyke screen that would inhibit departure of fish following entry into the trap.

Lifting of the trap would be performed using a mechanical lift system. Hydraulic lift systems could be used, but could result in accidental discharge of oil. It is expected that noise associated with a properly design and maintained lift system would be minimal, and could be further controlled by enclosing the lift structure inside of a paneled superstructure.

Discharging of fish from the trap can be performed by volitional swimming with a "crowder" or by emptying of the trap (e.g., tipping) using a mechanical system; the latter approach is recommended. Fish would be discharged into a sorting facility were non-target species would be manually removed. The sorting facility would be comprised of tanks with a constant water supply. The size and number of sorting tanks would be determined based on the number of fish requiring handling. Unsorted passage may be possible under some conditions if determined appropriate (e.g., when it is determined that no undesirable species will be present in the lift.

Design and Operational Requirements

Primary design components of fish elevators have constraints associated with the need for continuous mechanical operations during seasonal migration periods to provide for upstream fish passage. Existing access for construction and operation of a fish lift is limited to the left (north) abutment of Ballville Dam. While the non-overflow section of the dam between the left and right spillways has bays that could, conceivably, be used to house a fish lift, this location is impractical because of poor access (i.e., across a footbridge), potential for floods overtopping the structure, and lack of suitable covered space for sorting/exclusion operations. Figure 1 provides a conceptual layout of what a fish elevator system may look like at the Ballville Dam.

Typical components of a fish lift include 1) siting at an appropriate location along the downstream side of the dam, 2) provisions for suitable attraction flow to guide fish into inlet, 3) a trap system, 4) a lifting system, 5) sorting system, and 6) a fishpass outlet. General concepts for each of these six components for a fish lift at Ballville Dam are described below;

1) **Siting**: The area adjacent to the left abutment of the dam appears to be generally suitable for installation of a fish lift. A primary requirement is that the structure be located where it is not subject to damage from flow passing over the north spillway. This is generally as depicted on the figure "Fish Lift North Abutment."

2) **Attraction Flow**: Attraction flow into the trap is necessary to guide fish into the trap section at the base of the fish lift. The general configuration of this system will be similar to a flow-through fishpass. The design of the attraction flow requires information on hydraulic conditions in the area immediately downstream from the north spillway and

further downstream. Selection of an appropriate attraction flow discharge and orientation of the attraction "jet" at the base of the dam would need to be evaluated based on a range of flows during the seasonal upstream passage period(s). In general, it is suggested that the attraction flow should be parallel to the retaining wall that extends downstream from the north abutment of the dam.

The volume and jet velocity of the attraction flow depend on a variety of factors; a conceptual estimate of total attraction flow is 50 cubic feet per second (cfs), comprised of 25 cfs discharged through the trap system and 25 cfs of augmented attraction flow discharged into the plunge pool in the immediate vicinity of the trap inlet. Both the trap system and augmentation flow can be provided using conduits from the upstream impoundment with appropriate controls and fittings (e.g., valves, diffusers).

It must be verified that the target fish species are able to ascend to the plunge pool immediately downstream from the north spillway prior to final site selection. Given the general unsuitability of the south abutment of the dam, modification of the downstream channel may be appropriate if barriers to upstream passage are identified downstream from the north spillway.

3) **Trap System**: The trap system is generally located upstream from the fishpass entrance. In general, the trap may be viewed as similar to a fyke net, with fish passing through a narrowing slot prior to entering the trap that is part of the lifting system. Attraction flow (assumed here as 25 cfs) must be routed through the trap system, and requires a barrier fence at the upstream end of the trap. A temporary closure fence would be required at the inlet of the trap; this fence would be closed prior to lifting and reopened upon completion of a lifting cycle when the trap is returned to the bottom of the trap well.

4) **Lifting System**: The lifting system is comprised of a "lift bucket" to allow fish to be persistently wet during vertical transport. The lift bucket must be sized to accommodate expected numbers of fish and the largest size fish that may be expected. It is recommended that the minimum internal dimension be at least 6 feet. The volume of water in the lift bucket must be sufficient to limit the potential for asphyxiation of fish due to oxygen depletion during lifting. Based on an assumed lift speed of 0.5 ft/second and a lift height of 30 feet, the duration of lifting would be 60 seconds, and asphyxiation is therefore not identified here as a primary constraint on operational effectiveness.

   A conceptual lift bucket volume is 4 feet x 6 feet with a depth of water of 2 feet, or 48 cubic feet (~ 360 gallons, 3,000 pounds). Screening along the side would allow for draining-off of water during lifting and containment of fish. Note the reported weight is similar with/or without fish as they displace water. This is a large lift bucket; in practice, the actual dimensions could be reduced.

   Various types of mechanical and hydraulic systems may be appropriate for the lifting mechanism. In general, the use of hydraulic systems is not recommended due to the potential for release of hydraulic fluid in the event of a system failure (e.g., burst hydraulic line). A mechanical chain hoist or winch system is recommended.

Auto cycling of lifting and gate operations is a possibility, but would not eliminate the need for sorting if exclusion of undesirable species is required. It is expected that a fish lift at Ballville Dam could be cycled (up and down) in approximately 15 minutes. During periods when numbers of migrating fish are low, it is expected that filling of the trap would represent the limiting factor on cycle time.

5) **Sorting System**: Exclusion of undesirable species would likely be required as part of fish lift operation at Ballville Dam. It is expected that removal and disposal of upstream migrating sea lamprey would be required at any upstream fish passage system at Ballville Dam. A lift or lock system would facilitate this, and would require construction of a trapping and sorting facility; such a facility would be best located at the fish lift outlet. This system would require holding pools and means to effectively sort, capture, and dispose of undesirable species.

6) **Fishpass Outlet**: The fishpass outlet should be located well upstream from the north spillway. Depending on the target species and life stages for upstream passage, detailed hydraulic studies may be necessary to assure that fish can successfully move upstream from the fishpass outlet with minimal risk of being swept downstream and over the spillway.

Discussion of Previously-Noted Issues

- Aesthetics: A properly designed and constructed fish lift would be marginally visible.
- Operation of mechanical systems is not expected to result in noise in excess of that produced by water flowing over the dam.
- The likelihood of breakdowns of a properly designed and maintained system is not expected to occur

Downstream Fish Passage

Fish elevator systems are not used for downstream fish passage. The suggested approach to accommodate downstream fish passage at Ballville Dam is to construct a notch in the north (river-left) spillway that is the primary flow pathway at lower flows. Suitability of downstream passage over spillways generally requires a downstream plunge pool depth of at least 25 percent of the hydraulic height of the structure. At an approximate hydraulic height of 30 feet, the minimum plunge pool depth would need to be 7.5 feet.

Design Criteria for Ballville Dam

The objective of a fish elevator system is to provide for upstream passage of target fish species at Ballville Dam, including walleye, white bass, and greater redhorse. A fundamental component of fish elevator systems is trapping of fish prior to lifting the elevator component for release upstream. Fish elevators, therefore, do not provide for volitional upstream fish passage. A beneficial component of fish elevator systems is that they provide for trapping of fish which allows for exclusion of undesirable and/or invasive species, such as sea lamprey (*Petromyzon marinus*) and a variety of Asian carp.

Target migration periods for the three target fish species for upstream passage at Ballville Dam are presented in Table 1 along with seasonal flow statistics that were developed as part of the Ballville Dam Removal Feasibility Study (FS). A fish elevator system is not necessarily as constrained as a flow-through fish passage system (e.g. fish ladder) by low and high flow conditions, and, conceptually, may function at a broader range of flow relative to a flow-through system. However, fish must be able to reach the entrance to the fish elevator system and must be able to successfully exit the system and proceed upstream.

Based on a presumed requirement for upstream fish passage at a range of flows between the 75^{th} and 25^{th} exceedence percentiles, the range of flows during which a fish elevator at this site should provide for safe, timely, and effective upstream fish passage for the target fish species is from approximately 150 to 2,500 cubic feet per second (cfs).

Table 1: Seasonal Migration and Staging Periods for Target Fish Species

Fish Species	**1-Mar**	**15-Mar**	**1-Apr**	**15-Apr**	**1-May**	**15-May**	**1-Jun**	**15-Jun**
Walleye								
White Bass								
Greater Redhorse								
	Monthly Hydrologic Statistics (cfs)							
Flow Statistic	March		April		May		June	
75% Exceedence	510		467		288		156	
Median	954		1020		476		341	
25% Exceedence	2,490		2,400		1,075		800	

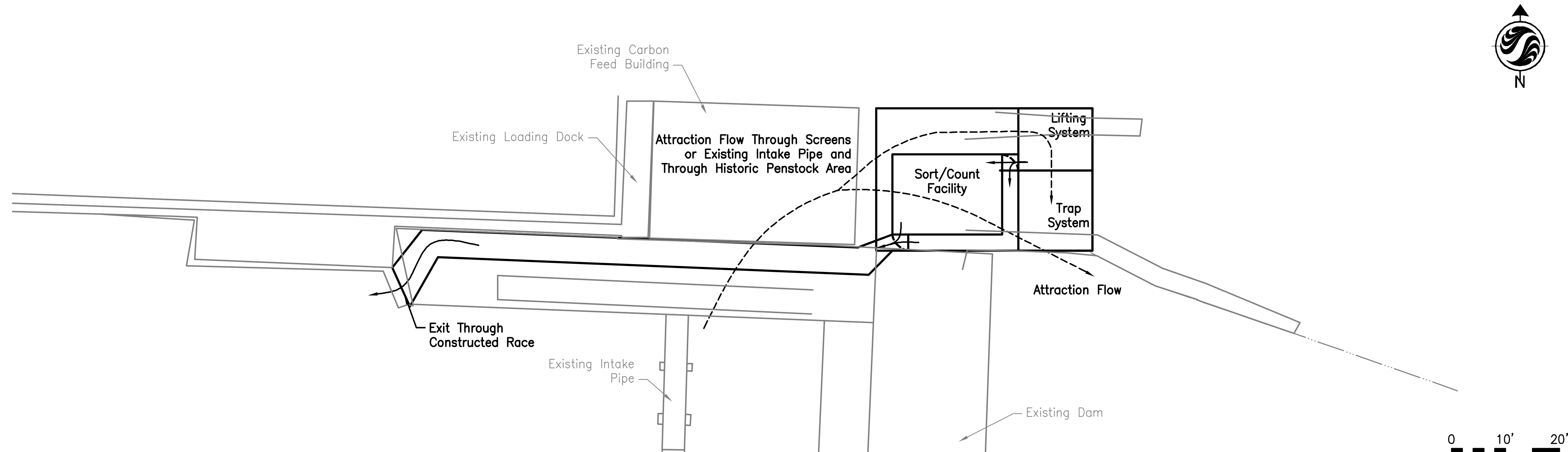
= Low-Level Activity
= Peak Activity

This alternative would include the concrete repairs to the dam, stabilization of the sea wall, and development of operation and maintenance manuals as described in the No Action Alternative. Additionally, it would require the construction of the elevator structure. A conceptual opinion of probable cost presented in the 2011 Ballville Dam Removal Feasibility Study is shown below.

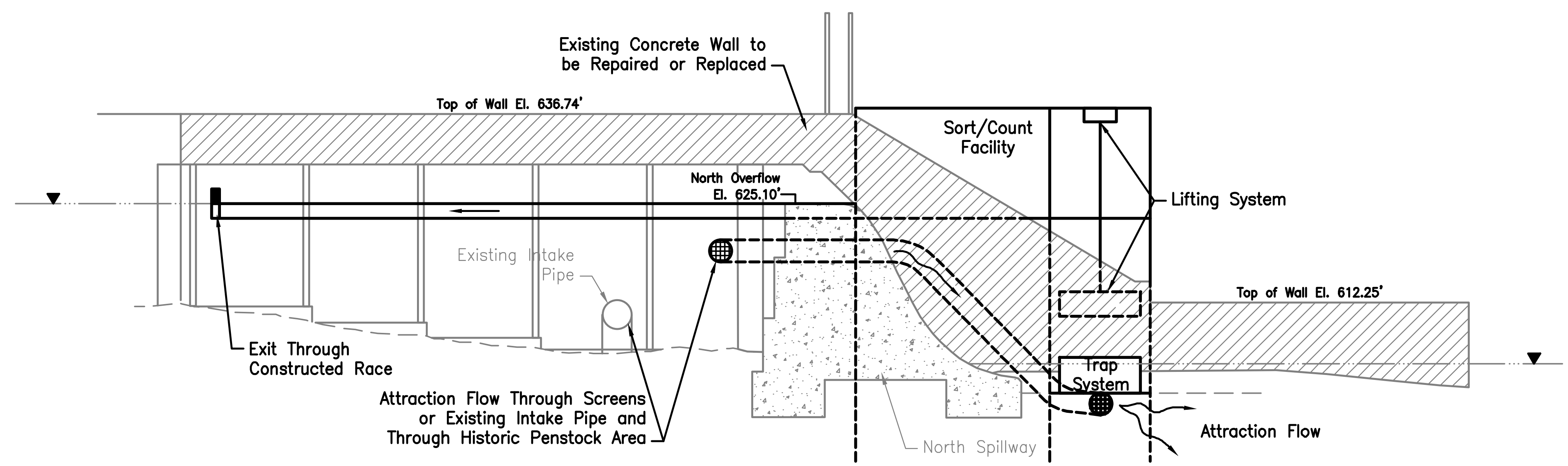
Opinion of Probable Cost for Fish Passage Facility

No.	Item	Total Cost
Construction Phase		
1	Coffer dam	$150,000
2	Tailrace excavation	$250,000
3	Fishway foundation elements	$200,000
4	Steel superstructure (structural elements)	$225,000
5	Fishway controls (mechanical elements)	$175,000
6	Fishway attraction flow piping	$350,000
7	Volitional channel, control gate	$300,000
8	Construction phase engineering support	$90,000
9	Construction QA/QC	$120,000
	Total Construction:	**$1,860,000**
	Construction Contingency (30 percent)	**$558,000**
Operation & Maintenance		
1	Annual Labor	$70,000
2	Annual Miscellaneous Maintenance	$5,000
3	Fishway Control Replacement (Annuitized over 15 years)	$17,500
4	Capitalized Cost (assuming 2 percent interest per year)	$4,625,000
	Total Capitalized Operation & Maintenance Cost:	**$4,717,500**
Design and Permitting		
1	Additional Dam Safety Analyses	$150,000
2	Additional Subsurface / Geotechnical Exploration	$100,000
3	Design of fish passage - Modeling and agency coordination	$100,000
4	Design of fish passage - Structural	$150,000
5	Design of fish passage - Mechanical	$80,000
6	Permitting	$200,000
	Total Design and Permitting:	**$780,000**
	Total Fish Passage Costs:	**$7,915,500**

Attachment: Conceptual Layout of Fish Elevator at Ballville Dam



PLAN VIEW – FISH ELEVATOR



ELEVATION VIEW – FISH ELEVATOR

April, 2013

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Notes

Client/Project
City of Fremont
Ballville Dam Removal

Figure No.
1

Title
Conceptual Layout of Fish
Elevator at Ballville Dam